RECYCLING CARBON-ENRICHED FLYASH INTO A UTILITY BOILER

Michael E. Coates
e-mail: coates@neesnet.com
phone: (508) 389-3098
fax: (508) 389-3663
New England Power Service Company
25 Research Drive
Westborough, Massachusetts 01582

Allen W. Sload
e-mail: sload@neesnet.com
phone: (508) 740-8211
fax: (508) 740-8358
New England Power Company
Salem Harbor Station
24 Fort Avenue
Salem, Massachusetts 01970

ABSTRACT

An electrostatic separation process has been implemented at New England Power Company's coal-fired stations to produce a saleable low-carbon flyash product. The byproduct (dubbed "Carbon-Rich") of this electrostatic separation process is a material that contains a large fraction of carbon.

The R&D Department sponsored a project to design, procure, install, and test a Carbon-Rich injection system at Salem Harbor Station. Several laboratory tests were performed to characterize Carbon-Rich as a fuel and to select the best injection location in the 88MW furnace. Field testing was performed to measure carbon utilization and emissions impacts resulting from Carbon-Rich injection.

SUMMARY

Background

In 1992, as part of its environmental plan, New England Power Company (NEP) committed to recycle all of its coal-fired flyash by 2000 A.D. At that time, two-thirds of NEP's flyash was not suitable for any known high-volume recycling use due to high loss-on-ignition (LOI). As a result, less than one-tenth of the total flyash produced was being recycled. After identifying and screening several flyash beneficiation processes, a series of R&D projects were begun in 1993 to validate the most promising options. One process seemed to hold commercial promise and in late 1993 a commercial-size demonstration project was initiated at Salem Harbor Station. In 1994 this demonstration project successfully separated, by dry electrostatic means and at commercial rates, raw flyash (12-18% LOI) into low-carbon product (less than 4% LOI) and a carbon-enriched byproduct.

In parallel with beneficiation process studies, several R&D projects investigated potential recycling uses for both the low-carbon product and the carbon-enriched byproduct. As the dry electrostatic demonstration project proceeded, high-volume use of the low-carbon product in concrete was successfully demonstrated. However, no near-term, high-volume, off-site uses for variable quality, carbon-enriched byproduct were found. During the 1994 electrostatic separation demonstration, NEP personnel conceived a plan to recycle the carbon-enriched byproduct on-site. The plan envisioned injecting the carbon-enriched byproduct ("Carbon-Rich") back into a coal-fired boiler in order to combust the unburned carbon in the separation byproduct. Several expected benefits to NEP by recycling Carbon-Rich on-site were identified:

- Landfill savings - Instead of sending Carbon-Rich to landfill, it would be recycled.
- Reduced fuel costs - If the carbon burned, energy would be recovered and coal would be displaced from the fuel stream.
- Increased flyash sales revenues - By consuming unburned carbon as fuel, eventually all flyash minerals would leave the site as saleable low-carbon product.

Test Program

A test program was developed to investigate the material handling and combustion characteristics of Carbon-Rich through an industry literature review, lab studies, and a field test. Before the end of 1994 the initial investigations and lab studies were completed, and field test equipment was installed. Initial field tests were conducted in 1995. Prior to field testing, a set of fifteen "Success Criteria" was developed by NEP. These described both short-term and long-term results which would be necessary to declare injecting Carbon-Rich into a boiler an acceptable means of recycling unburned carbon.

Many concerns were expressed about potentially negative impacts on particulate and gaseous emissions, precipitator performance, flyash handling systems maintenance, sootblowing frequency, slagging accumulations, boiler temperature distribution, flame stability, and load reductions. The most dominant concern was that the unburned carbon in the flyash would not burn when injected into the boiler; the industry literature review seemed to confirm this concern.

Laboratory tests showed that Carbon-Rich would handle like a low-density flyash, with the density varying directly with LOI. Calorimeter tests indicated that Carbon-Rich had a heating value that varied directly with LOI; the heating value of the fuel fraction was nearly identical to the heating value of pure carbon. A thermal-gravimetric analysis (TGA) indicated that Carbon-Rich had very little volatile matter, was less reactive than other bituminous coals, including its parent coal, but that it combusted completely at temperatures well below normal furnace temperatures. A series of drop-tube laboratory tests sought to characterize the combustion of Carbon-Rich under dynamic conditions. A matrix of combustion tests was executed to test different temperatures, residence times, and excess O_2 conditions. Carbon-Rich at two different LOI fractions (approximately 40% and 70% LOI) and the parent coal were tested at a number of simulated furnace conditions. Carbon-Rich performed well in the drop-tube tests. The test results showed that more than 90% of the unburned carbon burned out at furnace conditions that were readily available in the boilers at Salem Harbor Station.

Based on the laboratory tests, it was decided to perform field tests by injecting Carbon-Rich into the hottest part of the furnace flame using a dilute-phase transport and injection scheme. A variety of injection locations were chosen including single and multiple burners at either of two burner levels. Two injection methods were used: direct injection into the flame using a lance passing through the center of the circular coal burner and indirect injection by adding Carbon-Rich to the coal flow in coal pipes downstream of the pulverizers. Carbon-Rich LOI varied from 45% to 65% during field tests. Carbon-Rich flow was varied up to a maximum of 4% of the full-load heat input to the boiler. All tests were performed near full load. A testing contractor was employed during field tests to measure gaseous and particulate emissions and to gather flyash samples for analysis.

Results

Field test program results showed that Carbon-Rich injection into to NEP's Salem Harbor Unit #2 boiler passed short-term success criteria:

- Material handling and injection systems worked well;
- Opacity remained essentially unchanged;
- Particulate emissions remained acceptable;
- Gaseous emissions remained acceptable;
- Flame shape and stability were unaffected;
- Attemperation spray flows were unaffected;

- Precipitator power decreased;
- Carbon in flyash burned at good efficiencies (over 80%);
- Coal use decreased with no load reduction;
- Bulk flyash LOI decreased.

At the conclusion of initial field testing, NEP performed some continued testing to gain more confidence in carbon utilization analysis, improve familiarity with boiler operation, and identify long-term effects of injection. A conservative, simplified method of measuring and evaluating carbon utilization was developed by station personnel which demonstrated that Carbon-Rich burned at efficiencies at least as high as 80%. Control room engineers found that boiler operations were very easy to adapt to Carbon-Rich injection. No negative long-term effects of Carbon-Rich injection were observed.

Conclusion

Based on laboratory and field test results NEP has concluded that injection of carbon-enriched flyash separation byproduct into a boiler can:

- recycle unburned carbon on-site,
- lower landfill costs,
- lower fuel costs, and
- increase low-carbon product revenues.

R&D studies and demonstrations have concluded and NEP is in the process of implementing a Carbon-Rich injection program on its coal-fired generating units.